REQUIREMENTS FOR FIELD ARTILLERY MODELS OF COMBAT

by

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United States
Naval Postgraduate School

THESIS

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April 1970

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Requirements for Field Artillery

Models of Combat

by

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requirements for the degree of

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ABSTRACT

This thesis contains a qualitative analysis of the requirements for field artillery models of combat. The field artillery system and the artillery team along with the anatomy of combat are covered to familiarize the analyst with the major components of the system to be modeled. The treatment is presented from the modeling side in terms of desirable characteristics to be included and pitfalls to be avoided in a combat model and from the artillery viewpoint in terms of significant problems that exist in the areas of fire direction, target acquisition, and weapons evaluation. The analysis covers theoretical and working models of the above areas, which are in agreement with established facts of warfare. The conclusion reached is that future emphasis in combat modeling should concentrate on increasing the target acquisition capabilities of the field artillery.

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I. INTRODUCTION

> A great part of information obtained in war is contradictory, still a greater part is false, and by far the greatest part somewhat doubtful. What is required of an officer in this case is a certain power of discrimination, which only knowledge of men and good judgement can give. The law of probability must be his guide.

These words were written by Karl Von Clausewitz [Ref. 1] in 1827 on the subject of warfare in that era. They take on added meaning and become more significant when applied to the complexities of modern combat. Man has traveled far along the road to improvement of his capability to wage war successfully. Weapons systems have been developed which are capable of destroying almost any known target. Combat forces possess a degree of mobility that enables them to be deployed anywhere in the world and tactics have been improved through experiences on global battlefields. It is an obvious fact that modern combat is a dynamic interaction of weapons, terrain, personnel and tactics which are subject to change over time.

Tacticians and military analysts are constantly searching for ways and means by which the intricacies of combat can be studied in a precise and reproducible manner. Experimental wars cannot be conducted and combat cannot be reproduced in a laboratory. The long lead times and exponential rising costs of developing weapon systems requires that a thorough analysis be conducted and a strong probability of success be given to a system prior to committing scarce resources.

The discipline of Operations Research has made a significant contribution to the problem of analyzing present combat systems and developing improved systems by the introduction of the concept of the combat model. If the relevant characteristics of the situation can be isolated by means of a model then the problem can be analyzed and perhaps solutions or feasible areas for investigation can be identified which will result in a great savings in time, manpower, money and material. The model is not the ultimate answer to the analysis of warfare. It is a tool which, if properly used, can be of great assistance to the decision maker on whose course of action the outcome of future combat may depend.

The U. S. Army Field Artillery has realized the worth and unlimited potential of the use of combat models in conducting investigation regarding fire direction, target acquisition, and weapons evaluation.

The purpose of this thesis is to present and discuss the requisite characteristics of a valid field artillery model of combat and to illuminate those areas of field artillery operations in which combat models play a principal role in the problem solving process. A model of field artillery combat is considered to be valid or <u>good</u> when it is an understandable representation of reality using accepted mathematical techniques, with the ability to make feasible predictions regarding the situation or problem under analysis. This idea of a valid model combines the definitions of model validation and model verification as given by Dr. S. Bonder in Ref. 2.

A basic understanding of the field artillery system is an absolute necessity before attempting to develop a combat model of any field artillery operation. Such being the case, the major elements of the field artillery system are presented in an attempt to familiarize the reader with them.

The development of a new system in field artillery is an evolutionary process which most often proceeds along the path of a concept, to a theoretical model, to a working model and then to field testing or implementation in the hands of the troops. The examples of models which are presented in this paper are for the intended purpose of illustrating their role in this evolutionary process.

II. MODELS

A model is a representation of reality which abstracts the important characteristics of the situation relevant to the problem under consideration. The components of the model may vary from a set of mathematical equations such as Lanchester's equations, to a war game formulated as a computer program, to a verbal description of the situation in which analysis and decision must rely heavily on considered opinion and military judgement based on experience.

It is not possible for a model to represent all aspects of reality. However, it must be constructed so that the analyst can clearly understand the inputs, internal operation, and outputs of the system in order to adequately examine the operations of the system.

A. TYPES OF MODELS

A model is usually developed for a specific study or to solve some stated problem, and can be classified as one of three basic types listed in Ref. 3.

1. Iconic

An iconic model is constructed by scaling and describes in physical form a dynamic object or a system state at some instant in time. A sandtable representation of a battle is an iconic model.

2. Analogue

An analogue model uses one property to represent another. A topographic map which uses contour lines to represent altitude is an example of an analogue model.

3. Mathematical

A mathematical model of a system consists of a set of equations whose solutions explain or predict changes in the state of the system. Models in this category can be refined further into deterministic models and stochastic models. Deterministic models represent systems which are devoid of uncertainty and changes of the state of the system can definitely be predicted. The original Lanchester equations are deterministic models in that the output can be predicted with certainty for any given input. Stochastic models are those which include probability theory in their representation and in their output. This type of model has many applications when modeling combat because of the uncertainty of the situation and, at the same time, may be the most complicated, and troublesome to work with.

Mathematical models have many advantages over the other types of models. To develop a formal mathematical model of a situation requires a more thorough analysis of the situation and consequently results in a greater understanding of the system and a more concise problem formulation. This tends to make the over-all structure of the problem more comprehensible, reveals cause-and-effect relationships, and allows for expansion in an orderly manner.

A mathematical model is necessarily an abstract representation of the system which requires approximation and simplifying assumptions if it is to remain tractable. Yet it is this characteristic that allows mathematical models to be general, responsive to manipulation, and concise in terms of their output.

B. COMBAT MODELING

The ability to develop a good model of a system or situation is an art which must be learned through experience. There are no rigorous steps or sequence of events that an analyst can follow to insure the development of a model representative of a realistic situation. However, characteristics of a good model can be included in the one under development and areas which are known to be trouble spots can be avoided.

1. Characteristics of Combat Models

A good facility for or a feeling of being at ease with mathematics and a thorough knowledge of the system being modeled are basic talents the analyst must possess if one expects to formulate a valid model.

Generally the process of developing a model will start with a concept or an idea to be investigated or some specific questions to be answered. The next phase is accomplished by formulating a representation of the concept as a mathematical model, followed by manipulation of the model, analysis of output and refinement perhaps by a relaxation of assumptions or approximations.

Experience and judgement must be relied upon when deciding the relevance of factors to be considered in the model. A thought to keep in the forefront at all times is to hold the assumptions to a minimum and insure that the assumptions used are made explicit. A clear statement of the basis of the operation improves communication between the analyst and the decision maker and lends credibility to the recommendations.

Combat is not a situation where a static balance of forces is the primary state of the system. It is a dynamic interaction of numerous elements which include types of weapons, terrain, tactics, force composition, and personnel, all subject to change over time. A great deal of the complexity of combat stems from the intricacies of change. Other than experience itself the use of a model is the most effective means by which the complicated interactions can be studied in a precise and reproducible fashion.

The validity of a combat model can be thought of in terms of its ability to predict. A model of combat situation is difficult at best to test because experiences in combat are not reproducible and wars are not conducted for experimental reasons. Some may say that the Spanish Civil War was an experimental one in that Nazi Germany tested many of the weapons and tactics which were later used in World War II; but the situation is not analogous. Such being the case the most the combat analyst can aim for as stated by E. S. Quade in Ref. 4, is to seek answers to the following questions:

Does the model describe correctly and clearly the known facts of the situation or system?

When the parameters of the model are varied do the results remain feasible and if not, why not?

Is the model capable of handling special cases in which there is some indication of what the outcome should be?

Can the model assign causes to known effects?

2. Difficulties of Combat Modeling

A critique of an analyst's efforts is far easier than starting from the concept and providing a better alternative. Whereas there is no sure road to success in developing a model there are several traps to avoid while traveling this road. Some of the more common pitfalls of combat models are discussed and the interested reader is referred to Ref. 4 for a more general and comprehensive coverage.

a. Wrong or Erroneous Assumptions

Faulty assumptions can easily creep into the model when the analyst does not have a thorough understanding of the capabilities and limitations of the force composition, weapons, or material that comprise the system or a knowledge of the tactics employed in various situations.

b. Inadequate Problem Formulation

The formulation of the problem is the most important aspect of an operations research project. Failure to adequately allot the time so that a sufficient amount is spent on deciding what the problem really is often results in developing a model which gives the right answers to the wrong problem.

c. Following the Old School of Thought

This is an adherence to the idea that a particular concept was good enough in the past and there is no reason why it will not hold again or refusing to venture into new areas because the policy is against the decision maker. This train of thought is self defeating when applied to theoretical models.

d. Overconcentration on the Model

The analyst can stumble on this obstacle when one becomes so engulfed in building a perfect model that is a work of art or an end in itself and loses sight of seeking a solution to the overall problem.

e. Complication of the Model

The analyst must decide what is important and relevant, and proceed to solve the problem. Complicated formulas, or relationships so involved that attempt to treat every aspect of a complex problem simultaneously are impractical and the inability to reduce them to an understandable, tractable, expression often results in conveying little or no meaning. Criticism of the model and attempts to explain the model lead to additions to try and plug gaps which in turn compounds the already difficult task of interpretation. All aspects of combat cannot be treated simultaneously because of the magnitude of the variables. As the degree of complexity increases so does the errors and the difficulty of locating them.

f. Incorrect Use of a Model

A model is a device which the analyst uses to assist in providing recommendations to the decision maker. The output of the model should not be used as the decision rather than input to the decision maker. Often times one system may appear far superior to another but this fact must be considered in its proper perspective by taking into account the assumptions and limitations of the model. Care must be taken to avoid using the model output as the final word or as an unshakeable basis for an immediate decision.

Most models, although general in nature, are developed to solve a specific problem and have inherent assumptions and limitations which may be peculiar to the system being studied. The model cannot be used for a purpose other than which introduced without insuring that it is adequate for the new problem.

Modeling combat situations or systems is an effective method of studying and analyzing military conflict. However, it is not an end in itself. When the model output has been analyzed and recommendations are made then the military judgement and experience of the decision maker must play the deciding role. The considered opinion of the professionals must be called upon when it becomes necessary to choose among several alternatives when one cause of action does not clearly stand out above the others.

III. THE FIELD ARTILLERY SYSTEM

A preliminary requirement in the formulation of any model is a thorough knowledge of the system that the analyst is trying to model. A thorough understanding of the artillery system requires knowledge of its organizations, the roles or missions that the artillery is called upon to perform, and the environment in which the artillery conducts operations.

A. ROLE OF THE FIELD ARTILLERY SYSTEM

The general role of the field artillery is to:

1. Provide fire support to the maneuver elements, destroying or neutralizing those targets that are most likely to hinder the accomplishment of their mission.

2. Add depth to the battlefield by attacking reserves, command posts, logistical installations, and lines of communication.

3. Achieve fire superiority over enemy, mortars, artillery, and nuclear delivery systems within its area of coverage.

The successful execution of this general role depends upon the effectiveness with which the artillery system is organized for combat and assigned specific tactical missions.

The artillery system is organized to deploy and employ particular fire units such as howitzer, rocket or field artillery missile batteries. The elements of the system as listed in Ref. 5 are:

The weapon or firing unit

Target acquisition capability

Survey capability

Communications

Fire Control

Transport

Logistics

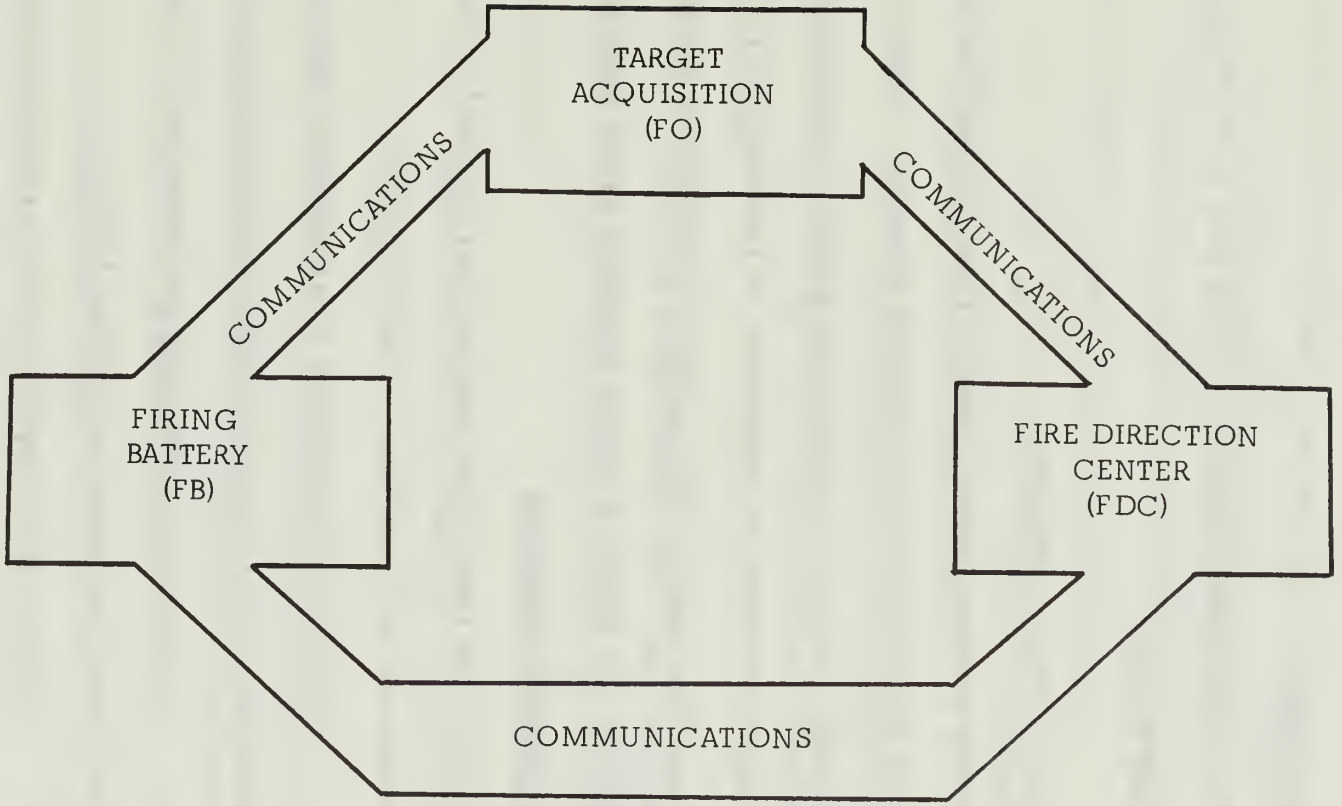
B. THE FIELD ARTILLERY TEAM

The elements of the system that the analyst is most concerned about for combat modeling are the weapon or firing unit which is commonly referred to as the firing battery (FB); target acquisition capability which is most often thought of as a forward observer (FO); and fire control in the form of the fire direction center (FDC). These elements are tied together with communications to form the artillery team as shown in Figure 1.

Each member of the artillery team performs a vital function which enables the artillery to fulfill its role of supporting the manuever elements. These functions are:

1. Target Acquisition

The observer (to include all target acquisition devices) detect and report to the fire direction center, the location and composition of targets, initiate requests for fire and conduct adjustments as necessary.



THE ARTILLERY TEAM

Figure 1

2. Fire Control

The fire direction center evaluates the information received from the observers, determines firing data, and transmits the data to the fire units.

3. Fire Units

The firing battery applies the firing data to the weapons and executes the fire mission.

C. MISSIONS OF FIELD ARTILLERY

The artillery performs several specific types of missions with its role of providing fire support to the maneuver elements. These missions can be listed under the type of operation the artillery is performing which are offensive or defensive operations. A knowledge of the missions within each type enables the analyst to translate the mission to targets for input to war games or combat models of target acquisition.

1. Offensive Operations

Some of the typical fire missions that the field artillery is called upon to execute during offensive operations are:

a. Attack enemy defensive areas (bunkers, base camps) and emplaced weapons (mortar, artillery and automatic weapon positions).

b. Destroy hostile command and communication installations such as tunnel complexes and fortified bunkers.

c. Deliver close support fires for maneuver elements and prevent enemy reinforcement by blocking movement of reserves with artillery fire.

d. Mass fires on targets during critical movements of attack to disrupt enemy forces and achieve suppressive effects.

2. Defensive Operations

Some of the more common fire missions that the field artillery is called upon to execute during defensive operations are:

a. Disrupt, delay, and disorganize the enemy's preparation for attack by firing on known and suspected enemy positions and likely avenues of approach into friendly positions.

b. Break up, with final protective concentrations and barrages, the enemy assault on friendly positions.

c. Limit enemy penetration with fire delivered within friendly positions and destroy enemy forces that have been canalized into killing areas.

d. Deny the enemy use of vital roads, railroads, bridges, mountain passes, etc., that can be used as approaches to friendly positions.

e. Support the counter attack and limited offensive operations such as patrols.

These fire missions listed above cover a wide variety under the categories of offensive and defensive operations. The Department of the Army has identified 28 important missions of the artillery which include 11 fire missions and 17 other missions. These have been

extracted from Ref. 6 and are listed in Appendix A. The analyst who is attempting to model the operations of a fire direction center must have a thorough understanding of these 28 missions.

D. RESPONSE ENVIRONMENT

Field artillery doctrine emphasizes the concept that the field artillery team must be endowed with a sense of urgency to insure the timely and accurate delivery of fire to meet the requirements of the supported units. Any unnecessary delay by any member of the team can result in the delivery of ineffective fire or the loss of a critical target. Every effort must be concentrated on the destruction or neutralization of a target while it is still a target. This fact becomes rather obvious when a target possesses a high degree of mobility.

In addition to speed, for artillery fire to be effective it must be of suitable density and must be delivered on target with the proper fuze and projectile. A round (fuze and projectile) which is effective against personnel in the open may have little effect against fortified positions and enemy armor.

Good target acquisition devices and procedures permit delivery of the most effective fires. Erroneous target location and limited observation result in greater expenditure of ammunition and less effective fire. Some type of observation is desirable for every target fired on to insure effective fire support. Observation of close-in battle areas is usually visual (air or ground observer) while observation of targets hidden by terrain features, poor visibility or at great distances can be

accomplished by electronic (radar, sound) methods. All available means must be used to deliver fire by the most accurate method that time and the tactical situation will allow. Inaccurate fire wastes ammunition, alerts the enemy and most of all reduces the confidence of maneuver elements in their artillery support.

The ultimate objective is to deliver a mass of accurate and timely fire so that the maximum amount of enemy casualties are inflicted.

E. COMBAT ENVIRONMENT

Artillery is employed and deployed both in width and in depth on the battlefield to provide the maximum amount of coverage to the supported forces. As a general rule the light and medium artillery units will be positioned so that they can accomplish their mission yet are out of range of the enemy's light artillery. Heavy or long range artillery units are positioned in depth so that they are out of range of the bulk of the enemy artillery. The exact positioning of firing units depends upon factors of which terrain and the actions of the supported units play a dominant role.

The maximum range of artillery weapons which are most commonly used to support maneuver elements are listed below from Ref. 7 to provide an idea of their capabilities.

Weapon	Maximum Range (meters)
105-mm howitzer	11,500
155-mm howitzer	14,600
8-inch howitzer	16,800
175-mm gun	32,700
115-mm multiple rocket launcher	10,600

Artillery performs its mission of support to the maneuver elements in many different areas of terrain such as jungle, desert, mountain, and swamp or marshland. These conditions must be accounted for in the scenario which is used during war games or a weapons evaluation study of alternative mixes.

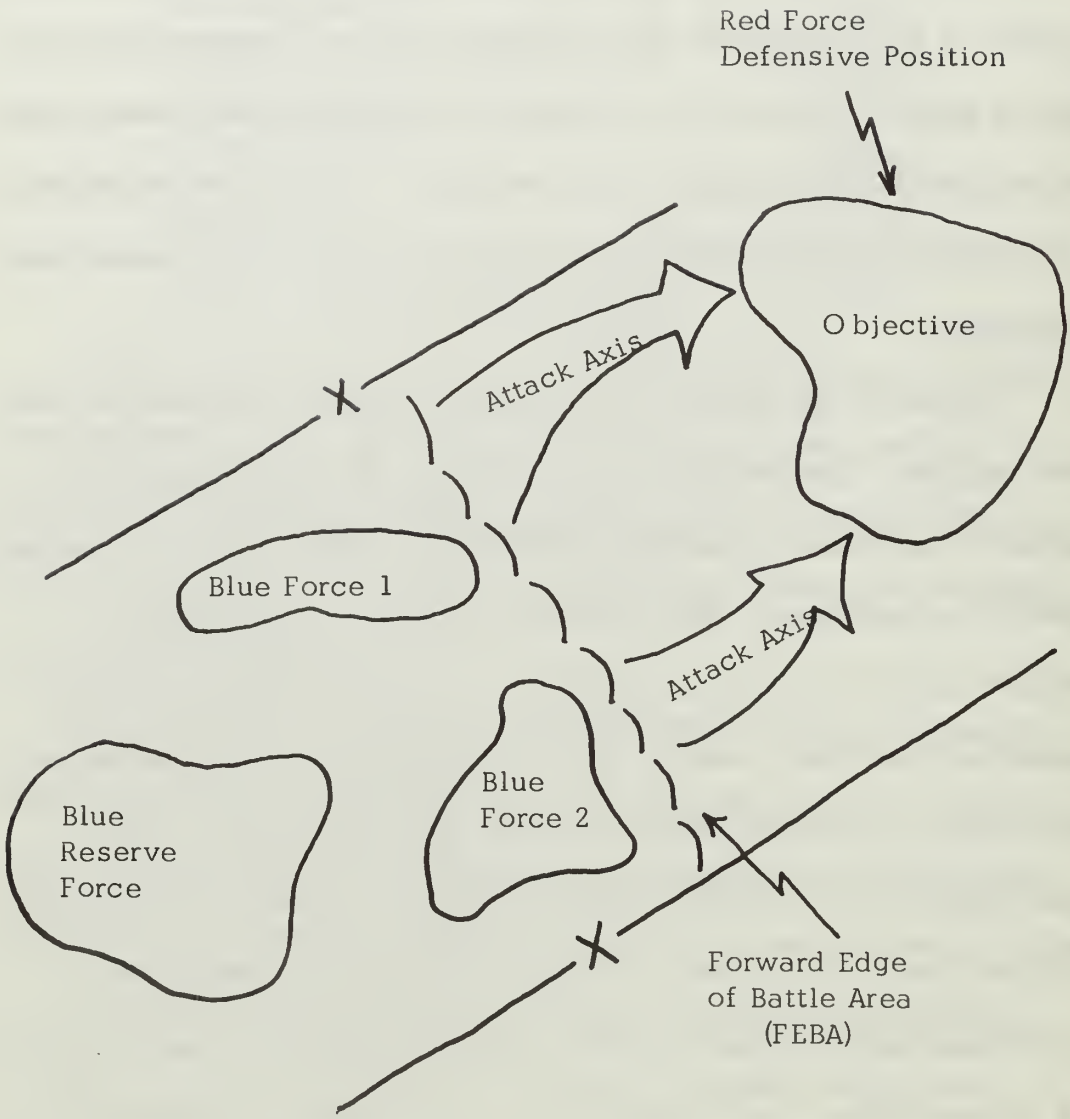
One sided combat, although easier to model, does not allow the analyst to realistically examine the performance of competing weapons systems. A unit which is under attack may not function as efficiently and smoothly as one which experiences little or no enemy counter action. Various states of combat have been included in models by defining an enemy threat and using scenarios of combat in Europe, Korea, and Southeast Asia. The levels of combat that have been used in models are classified as low intensity which is phase III guerrilla warfare, medium intensity which is combat similar to World War II and Korea, and high intensity which is nuclear warfare.

F. THE ANATOMY OF COMBAT

Before examining the areas in which requirements exist for combat models, it is advantageous to consider some of the elements that comprise a battle. Figure 2 is a schematic of an engagement between Blue Forces (attacking) and Red Forces (defending). The actions described in the following general discussion can be visualized with the aid of the schematic.

The battle begins from the Red Forces point of view when he has been assigned a defensive mission. The Red commander selects his defensive positions, establishes liaison with flanking units and issues orders to subordinates. When the Red forces are in position crew served weapons such as machine guns, and rocket launchers will be placed to cover likely enemy avenues of approach and final protective lines of fire. Anti-tank weapons will be emplaced to cover enemy armor approaches. Artillery and mortar defensive fires will be planned to harass and break up Blue forces in assembly areas and to disrupt any assault before it can reach the defensive positions. Red forces will dig in, camouflage, and if time permits, lay minefields and protective wire. The defender forces the enemy to come to him, to meet him on ground of his own choosing and then selects from several planned alternatives of fire support as the attackers action requires. The defensive plan will also provide for local counter-attacks, if necessary.

The Blue force (attacker) begins with reconnaissance to locate and define the defenders position area. The attacker will attempt to



SCHEMATIC OF BATTLEFIELD

Figure 2

gather as much intelligence about the defender before making an attack, but if the defense is weak or unprepared then the element of surprise may be the deciding factor. Once the Blue commander has formulated his plan of maneuver he will add the capabilities of his supporting artillery. Artillery preparations, to be fired prior to the attack, are planned on known and suspected defensive positions and weapons. Fires are planned along the axis of attack to support the attack and provide on-call fires.

The attacking force usually crosses the FEBA with preparatory artillery being fired to demoralize and destroy the enemy in position, disrupt the coordination of the defense and neutralize the defender's indirect fire support. The defenders may reply with counter battery fire and the result of this duel will be in favor of the most effective artillery. During this period of preparatory fires the attacker has moved to an assault line while the defender is firing on these positions.

At this stage the Blue force uses his artillery and direct fire weapons to neutralize the Red forces small arms, mortars, anti-tank weapons and artillery while the final assault may be by tanks, by tanks and infantry, either on foot or mounted in armored personnel carriers (APCs), or by dismounted infantry alone. The assaulting troops keep as close as possible to their own neutralizing fire, which finally has to shift to permit the final assault of 100 to 200 meters. The covering fire shifts to block any reinforcement of the position by the defenders reserve forces.

The defender in the meantime fires his final protective fires in an attempt to break up the attack before it can reach his position. If possible, and in any event when the attackers neutralizing and suppressive fire shifts, the defender fires his crew served and anti-tank weapons which may be spotted and engaged by the attackers covering fire, particularly by artillery forward observers or overwatching tanks. Attacking tanks will fire machine guns and main guns. If a defensive minefield is encountered, vehicles may be halted from 100-200 meters from the defensive position. From this distance tanks and APCs with machine guns and grenade launchers will saturate the defensive position. If an attacking tank reaches the defensive position, it will dominate all the area in its field of vision and the defense will be broken unless well dug in. If attacking infantry reaches the defenders position it will be overrun with some hand-to-hand fighting. Some defenders surrender, some attempt to withdraw with covering fire, others try to escape. Those attackers who have overrun the objective can engage the withdrawing or escaping defenders and along with artillery blocking fires, cause loser attrition almost without resistance.

If the attackers were beaten back during the assault, they would suffer additional losses from defenders fire as they withdrew. If the attack failed during the early stages the loser attrition would be light. However, if the attack failed at the last moment, loser attrition may end in annihilation.

In the event the attacker takes the defenders position, it is usually to the defenders advantage to conduct a counter-attack with a reserve force, supported by planned fire support, before the attacker can consolidate his forces and develop his own defense or coordinate his defensive fire support.

All the aspects of a battle have obviously not been covered in this general discussion. All the phases mentioned may not occur. Some may be changed with time, or omitted. Battles can be conducted without armor or artillery. Tactical air support was not considered nor were nuclear weapons included. Terrain may affect the strength of the defense and hinder or help tactical vehicles. Surprise is a great factor and a small force can destroy a large force in an ambush. Weather has been a deciding factor on more than one outcome of a battle. Light conditions play an important role during the conduct of the battle. Darkness sharply reduces the mobility of vehicles, practically blinds direct fire weapons and reduces single shot kill probabilities to almost zero. Poor visibility is an advantage to the attacker. Short range weapons such as small arms and rocket launchers have their capabilities degraded less than long range direct fire weapons such as tanks and recoilless rifles. Observed artillery fire loses some of its effectiveness in the darkness. Finally the morale, courage, or conduct of the individual soldier or unit was not considered.

The analyst cannot possibly hope to include all aspects of combat in a model and to attempt such a task would be self defeating. However, the analyst with a feel for the combat situation will start off with a better than even chance of formulating a model which is representative of reality.

IV. REQUIREMENTS FOR MODELS

The development of an operational field artillery system is an evolutionary process. The process will most often start with a mathematical model that is theoretical in nature. The analyst can control the parameters, manipulate the model, interpret and evaluate the output and hopefully come up with recommendations for future study in areas that appear feasible and susceptible to change. A theoretical model may infer, for example, when output is evaluated, that a particular force composition would increase combat effectiveness. This implication could further be investigated by incorporating the ideas in a working model of the operation in a combat situation. This working model may be an aggregate of several submodels, combined to provide an overall model for evaluating the effectiveness of alternate force mixes and assisting in the determination of force composition.

Requirements exist for combat models of the elements of the field artillery team to assist the artillery in answering the general questions of how should the artillery be organized; how can the artillery provide the most effective fire support; and with what weapons system should the artillery be equipped?

The actual task of developing models for the elements of the field artillery team cannot be restricted to the forward observer, fire

direction center, and firing unit. These specific elements must be expanded into areas of field artillery operation if maximum benefit is to be realized from combat modeling.

The operation of the forward observer must be expanded into phases of target acquisition which is used by the artillery. A great need exists for valid models of target acquisition systems which will enable the analyst to evaluate existing systems and develop future systems to increase the detection capability.

Operations of the fire direction center are extended to include both technical and tactical fire direction. These terms have been defined in the section which discusses fire direction models.

Combat models of firing units are readily extended into the areas of weapons system evaluation where the problem is to choose optimum mixes of weapons systems which maximize some effectiveness criteria.

A. THEORETICAL MODELS

The theoretical models discussed herein have been found to be in agreement with already established facts of warfare. The value of the models is in intrepretation of their output with the goal that perhaps the methodology may be applied to specific problems in the field artillery.

1. Lanchester Equations

The simultaneous differential equations formulated by F. W. Lanchester were probably the first attempt at the development

of models of combat. A comprehensive paper has been written by S. Bonder [Ref. 2] in which he has summarized Lanchester's theories of combat in a discussion of the works of analysts concerned with extensions of the original theory.

These rather well known basic equations and their solutions are discussed in Ref. 8 and 9 and presented below as a brief review.

The Square Law is applicable for situations of aimed fire and is derived under the assumption that:

a. Two forces are engaged in a fire fight when each unit or each side is within weapon range of all units of the other side.

b. Units on each side are homogenous but the killing rate of the opponent for each force may be different.

c. Each firing unit is well aware of the location and condition of opposing forces so that when a target is killed, fire is shifted to a new target.

d. Fire is uniformly distributed over the area in which surviving forces are located.

The opposing forces are designated as odd and even with the following notation:

x_1, x_2 = number of surviving units (men) on the even or odd side at time t.

x_{10}, x_{20} = initial strength of forces.

p_{21} = single shot kill probability than an even weapon will kill an odd man.

r_{21} = rate of fire of even weapons against odd units.

The Lanchester equations are:

$$\frac{dx_1}{dt} = -p_{21}r_{21}x_2;$$

$$\frac{dx_2}{dt} = -p_{12}r_{12}x_1.$$

The solution was obtained by integrating over time and equating results to obtain

$$p_{21}r_{21}x_2^2 - p_{12}r_{12}x_1^2 = p_{21}r_{21}x_{20}^2 - p_{12}r_{12}x_{10}^2 .$$

The solution yields the result that

$$\frac{x_{10}^2 - x_1^2}{x_{20}^2 - x_2^2} = \frac{p_{21}r_{21}}{p_{12}r_{12}}$$

where the ratio of losses squared is indirectly proportional to the effectiveness of the weapons. In situations where the Square Law applies the equations show that concentration of force is advantageous and warns against almost certain defeat to the side which commits forces piecemeal.

The Linear Law is applicable for modeling situations in which area fire is used. The first two assumptions of the Square Law are used along with the assumptions that

a. Each firing unit is aware only of the general area in which opposing forces are located and fire into this area without knowing the results of their fire.

b. Fire from surviving units is uniformly distributed over the area in which opposing forces are located.

The probability of opposing forces killing each other is a function of areas in the Linear Law. The following notation is included:

A_1, A_2 = areas in which the odd and even forces are located

ae_1, ae_2 = area of effectiveness (man) of a single shot

r_1, r_2 = rate of fire for an odd or even man

$PA_{12} = r_1 \frac{ae_1}{A_2}$ = effectiveness coefficient of even against odd.

The Lanchester equations for area fire are

$$\frac{dx_1}{dt} = - P_{A21} x_2 x_1;$$

$$\frac{dx_2}{dt} = - P_{A12} x_2 x_1.$$

The solution was obtained by integrating over time and equating results to obtain

$$P_{A21} x_2 - P_{A12} x_1 = P_{A21} x_{20} - P_{A12} x_{10}$$

From this solution it is seen that

$$\frac{x_{20} - x_2}{x_{10} - x_1} = \frac{P_{A12}}{P_{A21}}$$

The ratio of losses under the Linear Law are indirectly proportional to the weapons effectiveness coefficients and there is no advantage to be gained by concentrating forces.

The solutions of the Lanchester equations represent average values. The equations are an example of a deterministic mathematical model in that the outcome (rate of attrition) directly result from specified force sizes and kill rates which are the initial conditions.

Lanchester's Square Law and Linear Law can be modified by the addition of probability theory. The equations can be applied to many areas where theoretical and statistical investigations can lead to useful results. However, the original equations are limited and the analyst must bear this in mind.

The areas in which the equations depart from reality are discussed below. Much work has already been accomplished in extending the Lanchester equations by relaxing one or more of the assumptions. The equations assume in general that:

a. Each unit (man) is within range of all enemy units and that kill probability is constant and not a function of range.

b. All units on both sides are homogenous and therefore are not considering the fact that opposing forces may consist of infantry, artillery, armor, tactical air, etc.

c. There is no way to incorporate various levels or intensities of combat into the engagements.

d. No provisions are made for tactical decisions on the part of the commanders for employment of forces (mobility).

e. The equations do not include random events of probability theory.

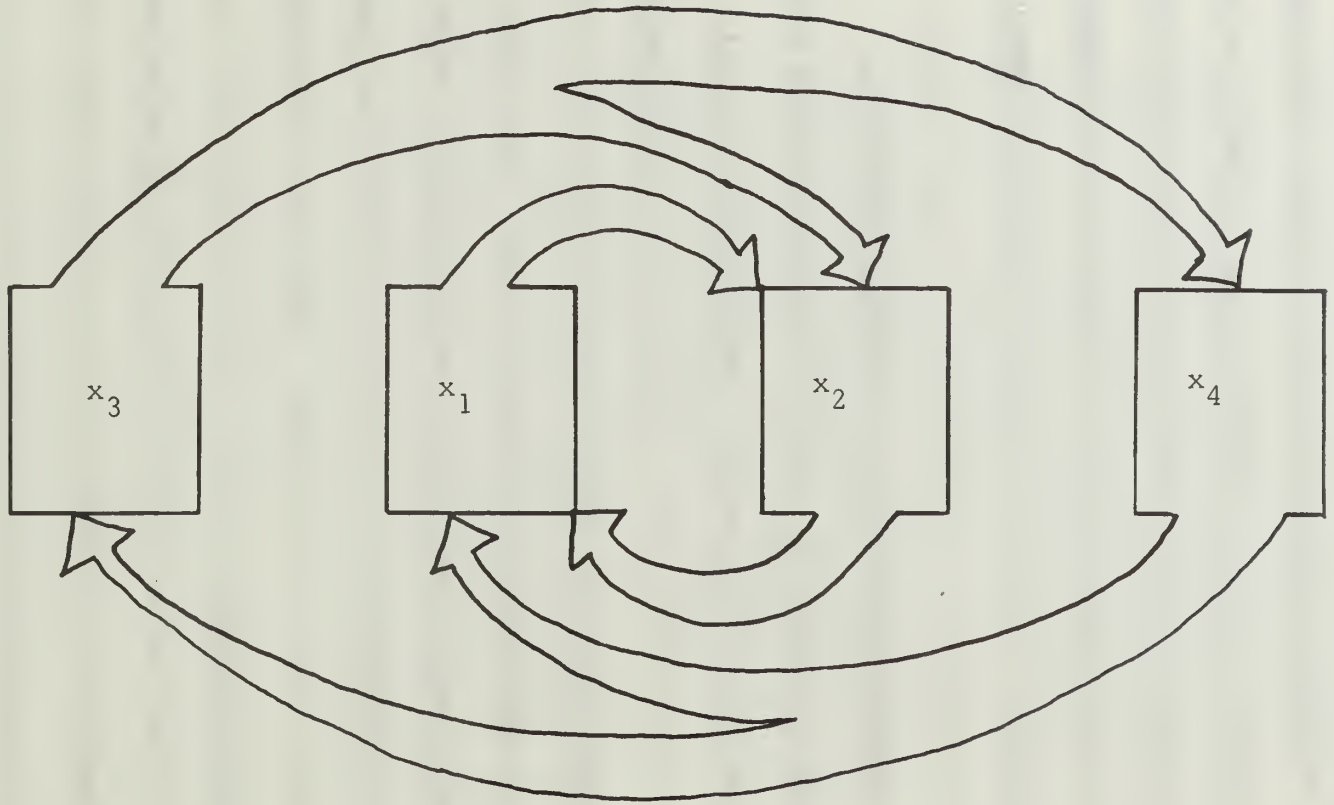
f. There is no way to vary the attrition coefficients over time.

Herbert K. Weiss has made significant contributions to the extension of Lanchester equations in models of combat. Reference 9 is particularly noteworthy because of the treatment that Weiss has given to relative movement of forces, combat between small forces in the presence of weapons with large areas of effectiveness and finally combat among heterogeneous forces. The problem of target assignment is covered when the forces are heterogeneous.

2. Examples of Models Using Lanchester Equations

One of the ways in which the original Lanchester equations depart from reality was that there are no provisions for tactical decisions by the force commanders. A valid analysis of modern weapon systems should be made with combat models that provide for tactical decisions by commanders during protracted combat. Weiss [Ref. 10] used Lanchester equations for a combat model in a problem which he formulated as a differential game. The tactic that Weiss has analyzed is the selection of targets to be attacked. This tactic is incorporated in his model which includes two forces in contact where each force consists of a primary and a secondary system. The primary system is maneuver elements such as infantry or armor and the secondary system can be thought of as field artillery or tactical air.

The battle as a function of time can be represented by Figure 3.



PRIMARY AND SECONDARY WEAPONS SYSTEMS

Figure 3

The Lanchester equations are

$$\frac{dx_1}{dt} = -k_{21}x_2 - \psi k_{41}x_4$$

$$\frac{dx_2}{dt} = -k_{12}x_1 - \phi k_{32}x_3$$

$$\frac{dx_3}{dt} = -(1 - \psi)\, k_{43}x_4$$

$$\frac{dx_4}{dt} = -(1 - \phi)\, k_{34}x_3$$

where

x_1, x_2 = the number of primary weapons (men) for odd and even at time t

x_3, x_4 = the number of secondary weapons (artillery air) for odd and even at time t

kij = rate at which the ith weapon can kill the jth weapon

ψ, ϕ = the fraction of surviving units of the 4, 3 type directed at weapons systems of the 1, 2 type

Optimum tactics are determined, using the above model, and the effects on force composition are also determined depending upon the weapon range, cost and performance parameters.

The problem becomes one of choosing the proper (ψ, ϕ) as a function of time. Weiss makes a further assumption that $k_{21} = k_{12} = 0$. This is saying that each side's secondary weapon system is so powerful that it will decide the outcome of the engagement before

the effect of the primary systems become significant. Weiss solved this problem by assuming that ψ and ϕ, the allocation variables, would only take on the values 0 or 1 and remain constant until termination of the battle.

Another application of a differential game of this type is, assuming that the game is played optimally, to determine how each side should divide a given budget between primary (infantry or armor) and secondary (artillery or air). Given effectiveness coefficients k_{32}, k_{41}, k_{34}, k_{43} and the unit costs C_1, C_2, C_3, and C_4, Weiss determines the budget ratio s_1/s_2 that must be maintained to insure a draw and the fraction of the budget that must be spent on each weapon system.

When weapon characteristics are taken into consideration, Weiss is able to apply his model with its assumptions and come up with recommendations for specific weapon types.

Weiss considered the value of supporting weapon system in the paper. This implies that the weapon system is one that has an area of effectiveness rather than point effectiveness. However, the Lanchester equations used in the model are those of the Square Law or aimed fire. If the Linear Law was used the model would have been too complex to allow the basic interrelations to be clearly identified. The model brings out results that can be investigated in greater detail by a working model in the form of a computer simulation.

Brackney [Ref. 11] in his work has extended the Lanchester equations to include the concept of search during combat for the

individual combatants of the opposing force. This development is made under the assumption that the distribution of a combat force, over an area held by that force, is uniformly random. The assumptions of Lanchester's Square Law for area fire are also present. The following is a summary of Brackney's work.

An M-force opposes an N-force and the rates of attrition are expressed by:

M-force action	N-force action	
$\frac{dn}{dt} = P_m r_m M$	$\frac{dm}{dt} = p_m r_m n$	(1)

r_m, r_n = rates at which opposing forces attack each other

m, n = size at any time t of M and N forces

p_m, p_n = probability of kill in encounters.

The reciprocals of the attack rate r_m and r_n are expressed by T_m and T_n in the following equations:

$$T_m = 1/rm = T_{sm} + T_{fm}$$
$$T_n = 1/rn = T_{sn} + T_{fn} \qquad (2)$$

The notations in these equations are:

T_{sm}, T_{sn} = the times required by individual M and N combatants respectively, to search for and find individual enemy combatants (acquisition times)

T_{fm}, T_{fn} = the time required by the respective combatants to fire their weapons (engagement times)

The characteristic attack times therefore comprise an acquisition time and an engagement time. The dependence of the acquisition periods upon the target densities existing over the target areas are expressed in the following equations:

$$T_{sm} = \frac{k_m A_n}{n} \quad ; \quad T_{sn} = \frac{k_n A_m}{m} \tag{3}$$

The k's are constants of proportionality and the A's refer to areas occupied by the opposing forces. The acquisition times are thus taken to be inversely proportional to target densities.

When the expressions (2) and (3) are substituted in (1) the following expression results for loss rates:

$$\frac{dn}{dt} = -p_m M/[k_m (\frac{A_n}{n}) + T_{fm}] ;$$

$$\frac{dm}{dt} = -p_n M/[k_n (\frac{A_m}{m}) + T_{fn}] .$$

Distinctive combat situations can be defined according to the relation of an individual combatant's search time (acquisition) to his firing or killing (engagement) time. Brackney considered cases only where the acquisition time was taken to be negligibly small or alternately very large compared to engagement time. Although not very realistic, this treatment simplifies computation. Nine combat situations were defined, using the modified Lanchester equations, and analyzed in light of ground close combat.

The target acquisition concept, which was expressed in explicit mathematical terms in Brackney's model, is essential to an adequate treatment of combat modeling. One of the most important aspects of combat is to rapidly and accurately acquire information concerning the disposition of enemy forces.

Col. Thomas S. Schreibert [Ref. 12] has developed a model using differential equations, which enables the efficiency of the intelligence and command and control systems (target acquisition concept) to be quantitatively related to the fire power and numerical strength of a force. Numerical results are presented which show that an increase in the target acquisition capability can be equivalent to a substantial increase in force strength. This result is intuitively appealing and implies that the combat effectiveness of a unit can be increased by improving the target acquisition capability of the unit.

Numerous treatments of Lanchester equations are available in the literature. The results of the above examples are of sufficient interest and importance to the field artillery to warrant rigid investigation.

B. WORKING MODELS

The second phase in the evolutionary process of developing an operational field artillery system may be to pursue the feasible outputs of the theoretical models by means of a working model. The model can take the form of a computer simulation, a war game, or explicit mathematical expressions by which present or proposed concepts can be evaluated.

1. Fire Direction

The concept of fire direction as presented in Ref. 7 includes both tactical and technical fire direction.

Tactical Fire Direction is the exercise of tactical command of one or more units in the selection of targets for immediate and pre-planned attack, the designation of units to fire, and the allocation of ammunition for each mission.

Technical Fire Direction is the conversion of requests for fire, from any source of acquisition, to appropriate firing data and fire commands.

The field artillery is constantly striving to improve technical competence in this vital area so that the maneuver elements can receive the most accurate and effective fire support available. Interesting problems are abundant in the area of fire direction which can be structured and hopefully solved with the aid of a model.

a. Areas for Investigation

A few of the more significant problems are presented to give an appreciation of their magnitude and varying degrees of difficulty.

The search for a better registration procedure than the one presently outlined in FM 6-40 is being considered. A statistical study of present and proposed methods with regard to comparative accuracies and number of rounds required would be an essential step.

Improvements in accuracy can be obtained by ballistically matching the family of projectiles within each caliber. This would greatly reduce the problems involved in computational procedures, firing tables, and training. The problem is to determine the increase in accuracy and resulting costs if this goal is to be obtained.

Probably the most difficult and complicated problem is the determination of individual factors that contribute to overall weapon system error. The system accuracy is determined by firing and consists of the square root of the sum of squares. However, it is not known which areas, of all those causing errors should be improved and to what extent from a cost effectiveness standpoint.

b. TACFIRE Effectiveness Evaluation Model

Efforts at improving the fire direction capabilities have been directed toward automation of the procedures. The greatest advancement has been the development of The Tactical Fire Direction System (TACFIRE) by Litton Industries which provides automation of selected field artillery operational functions. It consists of automatic data processing equipment and programs used by field artillery operations and intelligence personnel to support the maneuver elements during the 1970-1980 time frame.

A system effectiveness model was developed by Litton to evaluate progress in TACFIRE design and to serve as a vehicle for measuring overall TACFIRE performance.

A summary of the major components of the model as discussed in Ref. 13 is presented.

The complete TACFIRE Effectiveness Evaluation Model (TEEM) is an integrated set of three submodels, each designed for a particular analytical purpose.

The first submodel, Mission Execution Time Under Load (METUL) has the function of simulating TACFIRE response under conditions of varying fire mission load and mission mix. The model accepts technical and tactical inputs which characterize the state of TACFIRE and generate dynamic mission loads, simulates the processing of missions, and outputs system response measures such as mission response time, utilization factors for personnel and equipment and statistics for selected processing stages.

The analytical model for the Probability of State (AMPS) was designed to provide a tool for estimating TACFIRE system state probabilities. The inputs to AMPS are the rates at which components in TACFIRE go up or down. This submodel provides a capability to obtain information such as mean-time-in-state, state transition probabilities and time to restore operations. The primary function of the third submodel, System Performance Evaluation Criteria (SPEC), is to convert the output of METUL and AMPS into measures of TACFIRE effectiveness.

The automation of fire direction procedures and the development of TACFIRE is a major accomplishment which is going to effect not only the field artillery team but the entire field artillery system.

2. Target Acquisition

Improvements in weapon systems and fire direction capabilities have more than kept pace with the development of target acquisition systems. The conduct and outcome of tactical warfare depends more heavily than ever before on reconnaissance, surveillance, and intelligence.

The field of target acquisition is rapidly becoming the most important area in field artillery operations and must be given increased emphasis. An urgent need exists for valid models to evaluate present capabilities of detection devices (sensors) and tactics of employment and to develop improved target acquisition systems.

a. Areas for Investigation

Does the acquisition of targets determine the deployment of forces or does the employment of forces, during the conduct of battle, determine the targets to be acquired? A documented answer to this question has received increased emphasis in light of the mobility of modern combat and will have a significant effect on the organization of units for combat.

Models of target acquisition systems must be able to treat the problem of trade offs between accuracy of target location, timeliness of acquisition and completeness of acquisition.

Many experienced senior personnel lean toward accuracy of target location as the critical element. The overall delivery error of rounds on the target is a function of the errors in target location, fire direction, weapons system, and ballistics. One method of minimizing

this overall delivery error is to start at the beginning and minimize the error of the target location device (sensor). Therefore the effort should be placed on the development of sensors.

Timeliness of target acquisition can be presented as the critical element. Too great a delay in transmitting and processing target information may result in a lost target. The sense of urgency is stressed because of the mobility of many targets. If enough firepower is brought to bear then a target will be destroyed while it is still a target. This policy, if not used with a great deal of caution, results in wasting ammunition and may even lead to firing on wrong targets.

Probably the most difficult element of target acquisition to give adequate treatment is completeness of acquisition. This is the ability of a sensor to detect the size and or composition of a target. The amount of fire support allocated to effectively engage a target consisting of one enemy truck is much less than that required to engage a convoy of six trucks. The completeness of acquisition directly relates to the field artillery being able to underkill, kill, or overkill a target.

There is no answer in closed form that can be given to solve the problem of trade-offs but adequate treatment must be given in a combat model of target acquisition systems.

The problem of analyzing how target priorities change over the conduct of the battle is one in which combat models can assist in a solution. A standardized method of assigning target priorities is

of particular importance when applied to war games. The target lists and priorities have a direct bearing on the result of the game and the interpretation of results.

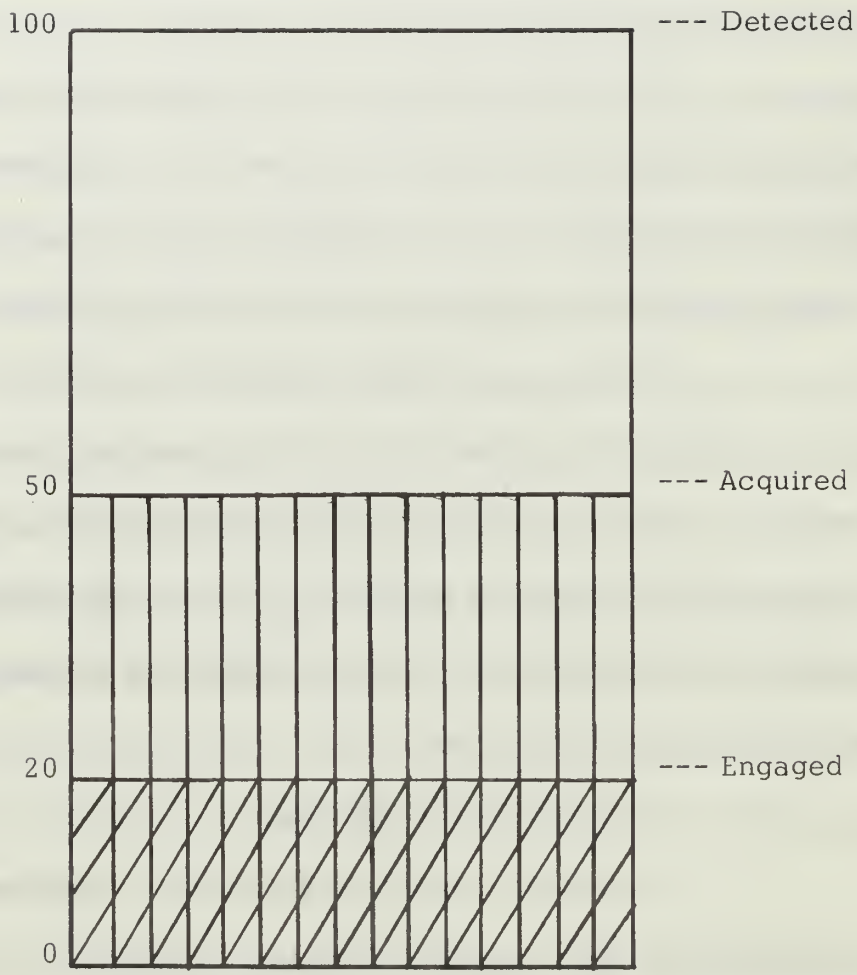
The field artillery has expended a great amount of its resources in an effort to solve what can be referred to as the detected-acquired-engaged difference as shown in Figure 4.

The values in Figure 4 are intended to represent a hypothetical situation of 100 targets detected. Out of the total detected 50 of the targets are located and identified or acquired, and 20 of the total targets detected are ultimately engaged by field artillery.

The purpose of this example is to illustrate the fact that not all targets which are detected can be engaged. Some of the reasons can be determined and every effort is being made to raise the levels of acquired and engaged to that of detected. When this has been accomplished the field artillery will be providing the ultimate in fire support to the maneuver elements.

b. Target Acquisition Model

The target acquisition model that is discussed below was developed by J. R. Payne [Ref. 1] and associates and is entitled Combined Reconnaissance, Surveillance and SIGINT Model (CRESS). It is an advanced analytical model of reconnaissance and surveillance systems suitable for use by U. S. Army agencies engaged in war gaming, simulation and analysis of alternate target acquisition system, ammunition-expenditure studies and intelligence/tactical operations center functions.



DISPOSITION OF TARGETS

Figure 4

CRESS is a model of the operational use of sensor systems and is composed of three major submodels: CRESS-A for aerial systems, CRESS-G for ground-based sensor systems, and CRESS-S for signal intelligence (SIGINT) sensor systems. It is modular in design and each of the three major submodels may be used independently of the others to process simulations of target acquisition functions up through Division-size forces.

The following types of sensor systems are incorporated in CRESS:

Photo
Infrared (IF) line scanner
Radar
Visual
Laser
Low-light-level television (LLLTV)
Passive night-vision devices (PNVD)
SIGINT

The simulation of the operational use of any collection of sensors of the above types produces; the target detection capability, the location accuracy, and the timeliness of reports as the basic measures of performance of the system. Each of the submodels has a computer program which performs all of the mathematical calculations. Player personnel must provide the input in the form of scenario development, target and sensor deployment, and intelligence analysis. Outputs of sensor performance are analyzed, revised intelligence estimates are made and the sensors are redeployed for another run.

CRESS is a definite asset to the field artillery. It can be used in studies designed to:

a. Compare alternate families of target acquisition systems.

b. Test advanced concepts will depend on the target acquisition capability of a force and

c. To generate target lists as input to an aggregate model.

3. Weapons Evaluation

The area of weapons evaluation is the most comprehensive in field artillery. Adequate evaluation of a weapon system must consider factors such as hardware, measures of effectiveness, organization of forces and costs. Lead time and associated costs involved in weapon system development are increasing at an exponential rate. The field artillery cannot afford the luxury of using scarce resources to develop and field a system which will not live up to its intended role. Models which are capable of evaluating present and proposed weapon systems are the answer to being right the first time.

The forthcoming introduction of TACFIRE will significantly increase the fire support capabilities of field artillery and revolutionize its operations. Such being the case, an urgent need exists to examine the entire field artillery system to insure that it is equipped, organized, and trained to fully utilize its capabilities.

a. Hardware

The evaluation of the hardware or the actual weapon itself is a responsibility of the Ordnance Corps and the Army Material Command (AMC). The field artillery establishes requirements for weapons based on accuracy, lethality, range, mobility and cost, to mention a few factors. The joint efforts of the Ordnance Corps and AMC are directed towards satisfying these requirements. All of the interesting work of weapons evaluation is by necessity classified. The Office, Chief of Ordnance publishes a report of the type listed in Ref. 14 every three years and these can be obtained by the interested reader who desires to pursue the subject further.

b. Measures of Effectiveness

A model which is designed to evaluate an artillery weapon system must have some measure against which alternatives can be compared. The task in choosing a good measure of effectiveness (MOE) can be most difficult and require a great amount of time and effort on the part of the analyst. The measures of effectiveness which are decided upon for a particular study must be understandable and accurate. Numerous measures have been proposed by analysts who have extensive knowledge of field artillery operations. A few of the more common measures of effectiveness are presented. They were developed for use in a particular model or study of a specific problem and cannot be construed as applicable for all field artillery problems.

The quantity of ammunition expended by type or by weight for each weapon mix can be used as a measure of logistical support required. The number of targets destroyed or total floor space destroyed by a weapon system is a measure which has been used when working with incremental effectiveness. Firepower scores have been developed for various types of weapons and have been used as a MOE. The difficulty encountered in using firepower scores has been one of trying to equate the scores of dissimilar weapons. The number of fire missions successfully completed is a measure of effectiveness which can easily be obtained for various mixes and is one of the most obvious.

c. Artillery Weapons Evaluation Model

A model for evaluating field artillery weapons systems is an aggregate of various submodels. The model developed by Charles T. Odom [Ref. 15] contained submodels for target acquisition, weapon deployment, effectiveness computations, and weapon-mission allocations. The model is designed for use in system analysis studies of artillery weapons, and was used to form the basic structure of the model used in the series of REDLEG studies. REDLEG III is the title of the computer model which was used in the USACDC study Optimum Mix of Artillery Units 1971-1975. The major features of the model have been summarized from Ref. 16 and are presented as an example of an aggregate model which is used in the evaluation of field artillery weapons mixes.

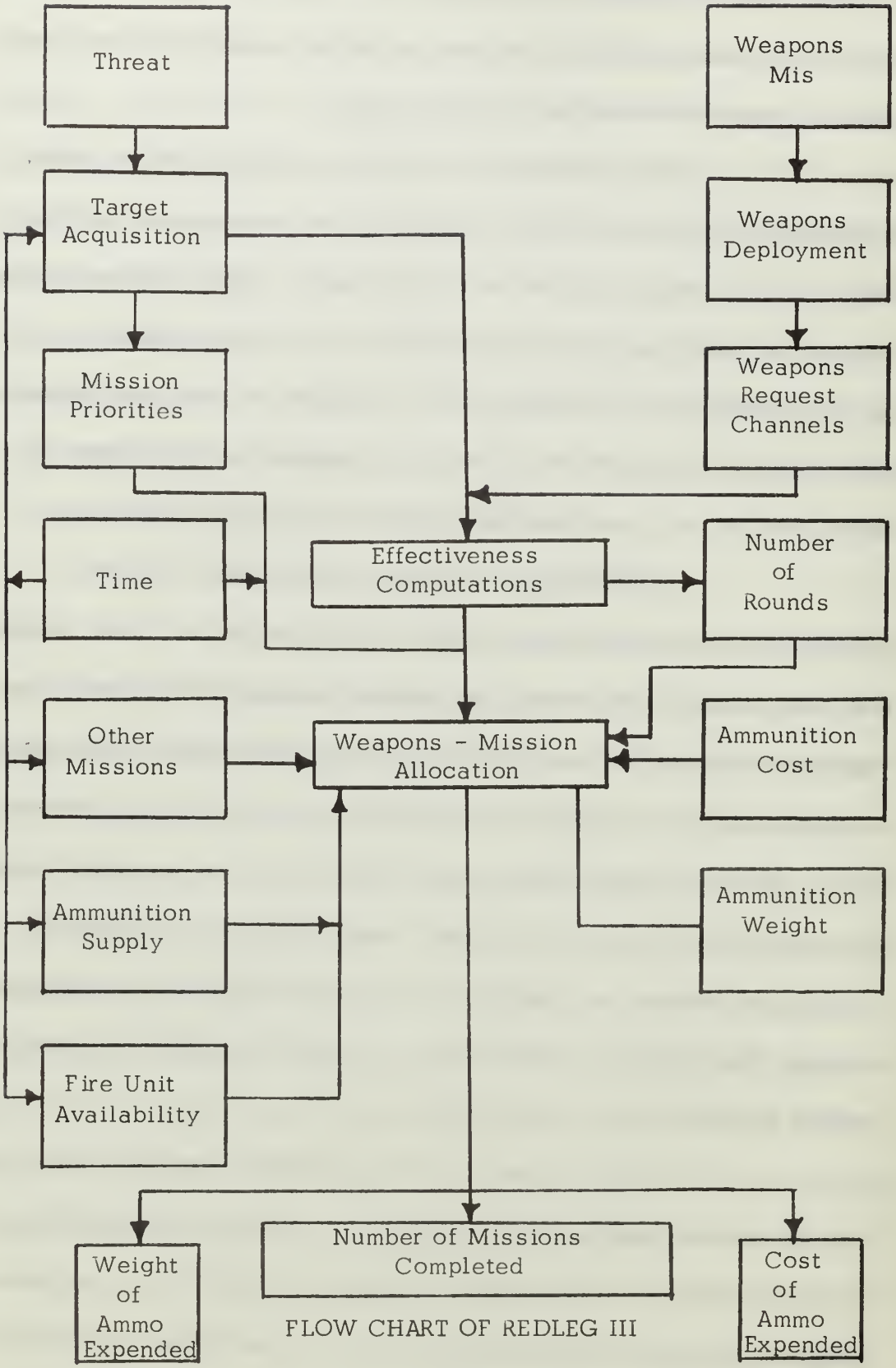
The major feature of REDLEG III is its ability to consider the time-dependent appearance of fire missions and the capability

of firing units to complete the missions. The model keeps track of the status of each firing unit and utilizes only those units which are available and capable of engaging a current target.

The introduction of the time concept into the model provides an analytical method for examining the variations of artillery firepower demands during the course of a battle. When firepower demands exceed firepower capabilities the artillery is in a surge situation. A surge situation exists according to Ref. 16 when the number of targets to be engaged in a short period of time is greater than the number of targets that the artillery force is capable of effectively attacking.

REDLEG III is shown as a flow chart in Figure 5. Inputs to the model are targets, other missions to be performed, weapons mix, and weapon effectiveness for attack of a given target type. The inputs are combined in a weapon-target allocation routine which assigns weapons to targets on the basis of effectiveness and fire unit availability. The basic output of the model is the number of available missions the artillery force is able to complete successfully. The weight of ammunition expended and the cost to maintain a capability are secondary outputs. The specific details of the model are described in relation to each of the blocks of the flow chart in Ref. 16.

A basic purpose of REDLEG III is to compare the capability of several weapon mixes to perform the missions required by a tactical situation. When a mix is specified the analyst can conduct a sensitivity analysis to determine the effect of variations in tactical,



FLOW CHART OF REDLEG III

Figure 5

logistical and command constraints on the capability of the mix. The experience and military judgement of the analyst must be called upon when conducting a sensitivity analysis to avoid the problem of examining situations which are tactically unsound.

The primary output of REDLEG III is the number of missions successfully completed by a given artillery weapon mix. This is a measure of the effectiveness for a weapon mix and can be used as input to a cost-effectiveness study.

The REDLEG III model is a significant improvement over previous models because of the incorporation of the time concept. It is a model which is used by USACDC to assist in the determination of an optimum mix of field artillery weapons. The model is a good representation of reality, tractable, flexible and subject to manipulation.

C. UTILIZATION OF COMBAT MODELS

Models of field artillery combat situations probably find their most extensive use as inputs to overall weapons systems evaluation and cost-effectiveness studies. The studies are made for example, to determine; optimum mixes of weapons for future force composition, to determine ammunition requirements, to determine overall logistical support requirements for various theaters of operation and also to determine personnel requirements.

Models are formulated and used by Department of the Army agencies for in-house studies. The Office Assistant Chief of Staff Force

Development, Office Chief of Research and Development, Army Material Command, Ballistics Research Laboratories, and the Army Combat Developments Command (CDC) are just a few of the user agencies. The CDC appears to be the most extensive user and developer of combat models. Models are the basic tool used in the studies conducted by the Institutes of Strategic Studies, Systems Analysis, Land Combat, and Combined Arms.

Numerous contracts are let to civilian research and analysis firms for the purpose of conducting studies or development of models. The models discussed in this paper, for the most part were developed in this manner. The Research Analysis Corporation (RAC), Combat Operations Research Group (CORG), Bunker-Ramo Incorporated, Thompson-Ramo-Woolridge (TRW), and Litton Industries are some of the prime contractors who assist the field artillery and the Army in solving the problems of how shall the forces be equipped, organized, and employed in an optimum manner.

V. AREA OF FUTURE EMPHASIS

The field artillery has made great advances in improving its fire direction capability with the development and forthcoming deployment of TACFIRE. New weapons and munitions have been developed which provide the commander with the capability of reaching out and destroying targets almost at will. The structure of our combat forces has been designed with a flexibility that permits rapid and effective employment and the associated personnel have been trained to a high state of readiness. However, in comparison to these improvements, the field artillery and the Army as a whole, has lagged in developing its combat intelligence capability in general and target acquisition capability in particular.

Future conflicts may not be waged along well defined battle lines and in cases of unconventional war like the one in Vietnam, target detection becomes a major problem. In fact, a nation's surveillance and detection capability may be a key element of survival in nuclear war.

Target acquisition systems with increased capabilities have been developed and in many instances, put into the hands of troops. This advancement is by itself not enough and the fact is well stated by Lt. Gen. Harry W. O. Kinnard [Ref. 17] who is a former commander of the 1st Cavalry Division (Airmobile) and former commanding general U. S. Army Combat Developments Command.

> But equipment alone does not necessarily improve the Army's capability. Devices used in surveillance and target acquisition must be matched with doctrine that prescribes their employment and a capability for processing information that will rapidly convert raw information into usable intelligence. The cycle is completed only when the resulting intelligence is transmitted and displayed to the troops who must engage the target or the enemy's forces.

Valid models have been developed in the areas of fire direction, weapons evaluation, and target acquisition. Examples of combat models which have been used to increase the capability of the field artillery in these areas were presented. It appears that a state of the art has been perfected to a fine degree in the first two areas and significant advancements cannot be expected without a major technological breakthrough. I am not an advocate of bringing progress to a halt in the areas of fire direction and weapons evaluation. Quite the contrary, for problems exist in these areas and must be given sufficient attention. I do feel that the military analysts have a better understanding of the significant problems in fire direction and weapons evaluation and possess the capability to come to grips with them and that solutions are within reach.

It is now time to channel our efforts and direct the emphasis towards bringing target acquisition capabilities of field artillery into line with those of fire direction and weapons evaluation.

The Combined Reconnaissance, Surveillance and SIGNET Model (CRESS) is a major step forward in the development and employment of target acquisition systems. Target acquisition is a function in which the demand, and the development of the capability to satisfy the demand

constantly stimulate each other and lead to increased capabilities. The field is unlimited and the gaps that exist can and must be bridged with improved target acquisition systems that have been analyzed and developed with the aid of combat models.

Department of the Army has realized the tremendous role of combat intelligence and has organized the Surveillance, Target Acquisition and Night Operations System Office (STANO) for the purpose of increasing the combat intelligence capability of the Army. The STANO organization will have members, according to Ref. 18 from the Army General Staff and command organizations such as the Army Material Command (AMC), Combat Developments Command (CDC), the Continental Army Command (CONARC), Army Security Agency (ASA).

Project MASSTER (Mobile Army Sensor System, Test, Evaluation, and Review) is a part of the STANO organization which will serve under the four commands; AMC, CDC, CONARC, and ASA, to perform integrated test and evaluation of STANO items.

STANO will combine systems, personnel, organization and doctrine in an integrated effort through studies, models, and systems analysis to insure the best utilization of the Army scarce resources.

The STANO organization has the resources to bring the intelligence and target acquisition capabilities to a level of advancement that has been achieved in fire direction and weapons evaluation.

APPENDIX A

IMPORTANT MISSIONS OF FIELD ARTILLERY

The twenty-eight important missions of the field artillery have been defined by the Department of the Army and are listed below. They consist of eleven fire missions and seventeen other missions. Tables which identify the personnel, equipment, and processing sequence for each mission are listed in Ref. 6.

(1) Fire Missions

(a) Battery Fire Direction Center (Btry FDC)

1. Area, Target of Opportunity, DS
2. Precision, Destruction, DS

(b) Battalion Fire Direction Center (Bn FDC)

3. Area, Target of Opportunity, DS
4. Area, Time on Target Fire for Effect (TOT/FFE), DS and GS
5. Precision, High Burst/Center of Impact (HB/CI), DS and GS
6. Precision, Registration, DS and GS
7. Precision, Destruction, DS and GS
8. Fire Mission, Missile Battalion (Msl Bn), GS

(c) Division Artillery Fire Direction Center (Div Arty FDC)

9. Fire Mission, Division Artillery

(d) Division Fire Support Coordination Element (Div F8CE)

10. Fire Mission, Div FSCE

11. Chemical Fire Mission

(2) Other Missions

(a) Battery FDC

12. Situation Report (SITREP)

(b) Battalion FDC

13. Situation Report (SITREP), DS, GS, and Missile Battalions

15. Survey, DS, GS, and Missile Battalions

17. Meteorological Message (MET), DS, GS, and Missile Battalions

19. Artillery Fire Planning, DS Bn

20. Artillery Fire Planning, GS Bn

22. Artillery Target Intelligence (ATI)

(c) Division Artillery FDC

14. Situation Report (SITREP)

16. Survey

18. Meteorological Message (MET)

21. Artillery Fire Planning

23. Artillery Target Intelligence (ATI)

(d) Division FSCE

24. Preliminary Target Analysis (PTA)

25. Nuclear Fire Planning (NFP)

26. Nuclear Target Analysis (NTA)

27. Fallout Prediction

28. Chemical Fire Planning

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13. ABSTRACT

This thesis contains a qualitative analysis of the requirements for field artillery models of combat. The field artillery system and the artillery team along with the anatomy of combat are covered to familiarize the analyst with the major components of the system to be modeled. The treatment is presented from the modeling side in terms of desirable characteristics to be included and pitfalls to be avoided in a combat model and from the artillery viewpoint in terms of significant problems that exist in the areas of fire direction, target acquisition, and weapons evaluation. The analysis covers theoretical and working models of the above areas, which are in agreement with established facts of warfare. The conclusion reached is that future emphasis in combat modeling should concentrate on increasing the target acquisition capabilities of the field artillery.

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